THE CONNEXION OF LIFE WITH RESPIRATION;

OR, AN

EXPERIMENTAL INQUIRY

INTO THE FFFECTS OF

SUBMERSION, STRANGULATION,

AND

SEVERAL KINDS OF NOXIOUS AIRS,

ON

LIVING ANIMALS:

WITH

An Account of the Nature of the Disease they produce; its Distinction from Death itself; and the most effectual Means of Cure.

By *EDMUND GOODWYN*, M.D.

Arteria animam accipit è pulmonibus. CICERO.

LONDON:

Printed by T. Spilsbury, Snow-hill,

For J. Johnson, in St. Paul's Church-yard.

1788.

WELLCOME
LIBRARY
INSTITUTE

Sanguineum laticem, turgens quem vena reportat,
Atque in pulmonum ſubito penetralia vibrat,
Imbibiturum illic, jam quidquid ab aëre ſumpto
Ætheris expreſſum eſt:——————
——————Motu, proh! quantum eſt artis in illo!
Vivimus hac fabrica tantum, ceſſante perimus:
Machina nam noſtra hæc non eſt hydraulica ſolum,
Pneumatica eſt etiam; auxilio ſpirabilis auræ
Indiget.——————

POLIGNAC, *Anti-Lucretius.*

TO

Mr. *JOHN PAGE*, senr.

OF

WOODBRIDGE, SUFFOLK,

THIS ESSAY

IS INSCRIBED,

AS A MARK OF GRATITUDE AND ESTEEM,

BY

THE AUTHOR.

ADVERTISEMENT.

AN unexpected emergence having called the Author of these papers to the Continent, just as he had sent them to the press; it is thought proper to mention the circumstance, lest any oversights, which he himself would have revised, should be found to have escaped in the printing.

W. W. P.

London, May 13, 1788.

CONTENTS.

Page

INTRODUCTION — — vii

SECTION I.

To ascertain the general Effects of Submersion on living Animals. — 5

SECTION II.

To determine whether the Water produces these Changes directly, *by entering into the Cavity of the Lungs; or* indirectly, *by excluding the atmospheric Air.* — — — 9

SECTION III.

To determine the mechanical Effects of the Air on the Lungs in Respiration. 21

SECTION

SECTION IV. Page

To determine the chymical Effects of the Air on the Lungs in Reſpiration. 48

SECTION V.

To determine the Nature of the Diſeaſe produced by Submerſion. — — 86

SECTION VI.

To determine the Condition of the Body in this Diſeaſe, and the Means of diſtinguiſhing it from Death itſelf. 99

SECTION VII.

To determine the beſt Means of curing the Diſeaſe. — — — 107

INTRO-

INTRODUCTION.

THE outlines of this Eſſay were publiſhed, about two years ſince, in the Latin language; and ſeveral of the moſt eminent profeſſional men honoured them with particular attention. A reception ſo flattering from intelligent criticiſm gave me an unexpected importance, and encouraged me to continue my labours with the hope of preſenting them to the publick in a more perfect form.

In the courſe of theſe labours many difficulties have ariſen, and much exertion has been employed; and ſucceſs has often favoured me: ſome queſtions however are

ſtill left undetermined, and ſome facts unexplained; but about theſe I am leſs anxious, as they are not immediately connected with the principal object of this Inquiry: and, although ſome ſmall obſcurities may ſtill remain, ſeveral facts are aſcertained, which will, I truſt, be of conſiderable uſe both in Philoſophy and Phyſick.

The reſpiration of animals has long been a difficult problem in Phyſiology, and no ſatisfactory ſolution could be given of it, whilſt Chymiſtry continued in an uncultivated ſtate: the general facts were indeed attended to, and conjectures propoſed to explain them (*a*); but as long as conjecture *only*

(*a*) Sir Iſaac Newton imagined that the atmoſpheric air might communicate an acid vapour to the blood in the lungs, which was neceſſary to keep up the action of the heart. OPTICS, p. 355.

only was uſed, doubt and uncertainty remained.

Within theſe few years the knowledge of chymiſtry has been much improved, and experiments have been applied to reſpiration with conſiderable effect; new facts have been diſcovered, extraordinary phænomena explained, and conſiderable obſcurities removed; but ſome difficulties ſtill remained to tempt the hopes of future labourers. In the courſe of this Inquiry I have carefully examined the facts deſcribed by others, and inſtituted a variety of new experiments, which ſeem to have aſcertained a principal uſe of reſpiration, its connexion with the motion of the heart and the other functions of the body.

The life of animals has alſo been a ſubject of attention at different times: for

until

until we are acquainted with ſome of its eſſential qualities, we cannot expect to diſtinguiſh it from death. The ancient phyſicians ſeem to have been aware of this; but they did not labour to ſupply the defect.

About the middle of this century two writers of diſtinguiſhed character entered upon the inquiry (*a*), and purſued it with great ardour and enthuſiaſm for a conſiderable length of time: in this purſuit they diſplayed much learning and ingenuity, and collected many valuable facts from the writings of others; but ſtill their concluſions were unſatisfactory, and their opinions are now fallen into neglect. This indeed will not be wondered at by ſuch as have examined their works; for it is generally obſerved

(*a*) Whytt and Haller.

obſerved of them, that they often blend hypotheſis with fact, and ſometimes graſp at more than the mind can attain.

After this time the ſtudy of life was generally neglected: however, ſome profeſſional men attempted to ſearch for the diſtinction between life and death in the ſenſible qualities of the body. Obſervations were collected, and ſeveral marks propoſed to the world to determine this diſtinction (*a*): but ſubſequent obſervation has ſhown them to be inſufficient; and, after much reſearch and altercation, it is now generally allowed, that we have hitherto no other means to determine

---

(*a*) Lettres ſur la Certitude des Signes de la Mort, par Monſ. Louis.

Diſſertatio an Mortis incerta ſigna minus à chirurgicis quam ab aliis experimentis. WINSLOW.

determine on abſolute death, but the preſence of putrefaction (*a*).

To avoid the ſources of theſe failures, I have endeavoured to conſider the ſubject in a different manner (*b*), taking the living body when all the accidental ſigns of life are removed, applying to it thoſe external powers which really do reſtore them, then attending to the place and circumſtances of their firſt operation, and the immediate effect they produce: thus I was led to the eſſential quality of life, and conſequently to the means of diſtinguiſhing it from death itſelf.

This

(*a*) Diſſertation ſur l'Incertitude des Signes de la Mort, par Monſ. Bruhier.

(*b*) Diſſertatio Inauguralis de Vita Corporis humani. Auctore J. T. Vander Kemp.

This diſtinction will be the more valuable, as it applies to every ſimilar ſtate of the body, whatever may have been the original diſeaſe; and if it be properly attended to, we may always determine with certainty, whether a perſon be really alive or dead; and the bodies of our friends may now be conſigned to the grave, before they become noxious to others.

But the benefits of this Inquiry have extended ſtill further.

From the reſult of the whole, I have been enabled to determine the nature of the diſeaſe that takes place from drowning, hanging, and breathing ſeveral noxious airs; to give it a deſcriptive name, and its proper place in the ſyſtems of noſology; and to point out the moſt effectual means of cure. Many remedies are recommended for this purpoſe in the directions of publick Societies

ties of different countries, and all of them are ſaid to have been employed with ſucceſs; and ſince the aſſertion is favoured by ſome of the moſt reſpectable authors, both ancient and modern, no one can deny it without incurring the charge of preſumption: but if it ſhould appear here, that animals may be recovered from the diſeaſe with equal eaſe, without the concurring operation of a great many of them, a regard to truth, as well as publick utility, ought to determine our choice. Beſides, when it is remembered that a prepoſſeſſion in favour of theſe remedies may occaſion a conſiderable loſs of time, and that a loſs of time in this diſeaſe is often a loſs of life, the intereſt of humanity ſhould riſe above general prejudice, and reſpect for authority give way to deliberate inveſtigation.

In the whole of this Inquiry, I have endeavoured to adhere cloſely to the method

of

of *Analyſis*, beginning with effects, and aſcending to their particular cauſes, and from particular cauſes to more general ones, with the aſſiſtance of *Analogy* and *Induction*, until I could proceed no further. Then I aſſumed the laſt concluſion as a general principle to explain the production of all the effects in a deſcending ſeries to the firſt phænomena, where the analyſis began; in this manner adding the *Syntheſis*, and thus giving to the reſult all the evidence which the nature of the ſubject would admit.

To avoid the danger of being miſled by the colouring of fancy or inaccurate obſervation, the experiments were repeated ſeveral times with great care and attention, and always in the preſence of ſome judicious friends: but as the teſtimony of the ſenſes is not always ſufficient, and the moſt careful inquirer may ſometimes err, I neither expect,

expect, nor even wish the conclusions should be adopted, until the experiments shall have been repeated by others; and if it be afterward proved, that I have been mistaken in any part of them, I shall readily retract the assertion, and acknowledge the error: for the interest of truth and the welfare of mankind are of more value than the reputation of an individual; and, as M. Bonnet properly says, "*Un* J'AI TORT *vaut mieux que cent répliques ingénieuses.*"

LONDON,
May 6, 1788.

SECTION I.

To aſcertain the general Effects of Submerſion on living Animals.

IN the courſe of this inquiry, we propoſe to aſcertain the general effects of ſubmerſion on living animals, and to trace their connexion with the action of the water on the body.

The firſt of theſe objects may be obtained by attending to the different changes that take place in living animals while they are immerſed in water, and examining the appearances of the internal parts when the body is taken out; and the ſecond, by obſerving the manner in which the water

is applied to the body in ſubmerſion, and tracing its particular operation in producing theſe changes.

For the firſt purpoſe, I procured a large tranſparent glaſs bell, that would allow me to diſtinguiſh accurately the circumſtances that took place within it; and when it was inverted, and filled with water, I put into it, at different times, ſeveral cats, dogs, rabbits, and other ſmaller animals, and confined them there till they had the appearance of being dead. As ſoon as they were put under the bell, I attended to the changes that took place in the body; and when they had loſt the external ſigns of life, I opened the head, the breaſt, and belly, and examined the internal parts.

Whilſt I was engaged in this buſineſs, the bodies of three unfortunate perſons, who

who had been drowned, were brought to me, at different times, with permiſſion to inſpect the internal parts: theſe I examined with great care and attention, and compared the appearances with what I had ſeen in the other animals.

In theſe different experiments, I obſerved ſome variations in the external morbid ſymptoms, and in the appearance of the internal parts; but the order and ſucceſſion of the ſymptoms, and the condition of the organs immediately connected with life, agreed uniformly with the following deſcription.

When an animal is immerſed in water, his pulſe becomes weak and frequent; he feels an anxiety about his breaſt, and ſtruggles to relieve it: in theſe ſtruggles he riſes towards the ſurface of the water, and throws

out a quantity of air from his lungs. After this, his anxiety increaſes; his pulſe becomes weaker; the ſtruggles are renewed with more violence; he riſes towards the ſurface again, throws out more air from his lungs, and makes ſeveral efforts to inſpire; and in ſome of theſe efforts a quantity of water commonly paſſes into his mouth. His ſkin then becomes blue, particularly about the face and lips; his pulſe gradually ceaſes; the ſphincters are relaxed; he falls down without ſenſation, and without motion.

If the body be immediately opened, it has theſe appearances:

1°, The external ſurface of the brain is of a darker colour than uſual; but the veſſels are not turgid with blood, nor are there any marks of extravaſation about them.

2°, The

2°, The cavity of the lungs contains a conſiderable quantity of frothy fluid; and the pulmonary arteries and veins are filled with black blood throughout their whole extent.

3°, The right auricle and ventricle of the heart are ſtill contracting and dilating; the left ſinus venoſus and auricle move feebly; but the left ventricle is at reſt.

4°, The right auricle and ventricle are filled with black blood, and the left ſinus venoſus and left auricle alſo; but the left ventricle is only about half filled with the ſame-coloured blood.

5°, The trunks and ſmaller branches of the arteries proceeding from the left ventricle, contain a quantity of this black blood alſo.

In the early ſtate of medical knowledge, and before anatomy was much cultivated, it was generally ſuppoſed, by different writers, that the water produced theſe effects on animals by ruſhing into all the cavities of the body, and rupturing ſome of the organs immediately connected with life (*a*). But ſince the ſtructure of the body has been more accurately examined, and the uſe and connexion of the different functions better underſtood, it appears evident that theſe changes are to be attributed entirely to the effects which the water produces on the lungs; either *directly*, by entering into their cavity; or *indirectly*, by preventing

(*a*) Galen. Lib. III. Comment. 40.—Ægineta, Lib. III. p. m. 97.—Ætius, Art. Princip. p. 404.—Alexand. Bened. Cap. III.—Codrongus de Submerſis, p. m. 322.—Senertus in Praxi, Lib. II. p. 350.

preventing the entrance of the air of the atmoſphere.

Several authors have endeavoured to diſcover by which of theſe means the water operates; and, after conſiderable labour and attention, they were greatly divided in their opinions: ſome contended for the former (*a*), and others for the latter (*b*). The concluſions, however, of both parties were generally drawn either from caſual obſervation, or from inſufficient and undigeſted experi-

 ments;

(*a*) *Platner*. Cent. Quæſt. Paradox. p. 35.—*Louis*, Mémoires ſur les Noyés, *&c. &c.*—*De Haen*, Ratio Medendi continuata, tom. 1, *&c.*

(*b*) *Littreus* and *Senac*.—Hiſtoire de l'Académie Royale des Sciences, anno 1719.—*Haller*, Prælect. Boerhaav. tom. 2. p. 219.—*Winſlow*, Experimenta Bruherii.—*Kaaw Boerhaave*, Impetum faciens, p. 228, *&c. &c.*

ments ; in conſequence of which neither of the opinions has been eſtabliſhed by its partizans ; and it ſtill remains a queſtion in phyſiology, which we ſhall next attempt to decide by experiment.

SECTION

SECTION II.

To determine whether the Water produces these Changes directly, *by entering into the Cavity of the Lungs*; *or* indirectly, *by excluding the atmoſpheric Air.*

IF the water enter into the lungs in drowning, we may naturally expect to find it there afterwards, when the body is opened: but if the body be opened after the obſtruction of reſpiration from any other cauſe, there is often a frothy fluid in the cavity of the lungs, reſembling a mixture of air and water, which might miſlead the inquirer.

In conſequence of this, it has been ſuggeſted to add ſome colouring ſubſtance to the

the water employed in experiments of this kind, that, if it ſhould enter into the lungs in the proceſs of drowning, the peculiarity of colour might ſerve to diſtinguiſh it from this frothy fluid: but if the coloured fluid ſhould enter into the lungs in a ſmall quantity only, the colouring matter may be ſo much diluted by the pulmonary mucus, as to loſe in a great meaſure its diſtinguiſhing character. On this account, it will be better to employ the deepeſt colours in theſe experiments, ſuch as very black ink, ſtrong ſolutions of blue vitriol, &c.

Experiment I.

I filled my glaſs bell with ink, and immerſed a dog in it. As ſoon as his ſtruggles ceaſed, he was taken out, and examined. A ſmall quantity of frothy fluid was found in the lungs, and it was coloured with ink.

The

The ſame experiment was made on three other dogs; and the fluid found in the lungs of each of them was coloured with ink. It was alſo repeated on three cats, and with the ſame general reſult.

From theſe experiments it appears, that ſome of the ink paſſed into the lungs of theſe animals; and we may infer from it, that a quantity of water commonly paſſes into the lungs of animals that are drowned: but it may be ſtill ſuſpected, that this water enters into the lungs by its own gravity, after the ſtruggles of the animals have ceaſed; and therefore that the preſence of water in the lungs cannot have occaſioned the ſymptoms which preceded.

This queſtion may be decided by putting the bodies of animals into a ſtate ſimilar to that which ariſes from ſubmerſion; and, after

after the ſtruggles have ceaſed, by plunging them into a coloured fluid: for if the fluid enters into the lungs in this ſtate, it may be inferred, that the ink alſo entered into them by its own gravity, after the efforts to inſpire ceaſed.

Experiment II.

I paſſed a ligature round the trachea of a dog, and ſtrangled him. As ſoon as he ceaſed to move, I plunged the body into a quantity of ink, and confined it there for ſeveral minutes. On examining the lungs afterwards, I found no ink in them.

This experiment was repeated on two other dogs, and with the ſame reſult.

Here we find, that the ink does not enter into the lungs by its own gravity, after

after the efforts to inſpire ceaſe. It muſt therefore have entered into the lungs of the animals of the firſt experiment during the efforts to inſpire.

But if the ink entered into the lungs of theſe animals during the efforts to inſpire, was it not ſufficient to produce the changes that took place in the body in conſequence of ſubmerſion?

To determine this queſtion, we muſt aſcertain the quantity of water that paſſes into the lungs during ſubmerſion, and the changes that are produced on the body by the introduction of an equal quantity of a ſimilar fluid.

If the ink which paſſes into the lungs would remain there in a ſeparate ſtate, we might aſcertain the quantity that paſſed into them in theſe experiments, by preſſing

it

it out again at the trachea: but this ink is ſo intimately combined with the mucus of the lungs by the agitation of the thorax, that we cannot collect it in a ſeparate ſtate. If, however, we employ ſuch fluids in theſe experiments as have no diſpoſition to unite with the pulmonary mucus, they will remain in the lungs in a ſeparate ſtate, notwithſtanding the agitation of the thorax, and may be in a great meaſure collected again.

Experiment III.

I filled a ſmall glaſs bell with quickſilver, and immerſed a cat in it, in the ſame manner as in the other experiments. When the body was taken out, I found half an ounce of quickſilver (*a*) in the cavity

(*a*) In weight.

cavity of the lungs, and an ounce of a frothy fluid (*a*) tinged with a red colour.

Three more cats were immerſed in quick-ſilver, in the ſame manner; and when they were removed, we obtained from the lungs of

	Quickſilver.	*Frothy mucus.*
The firſt, -	three drachms,	ſix drachms:
The ſecond,	five drachms,	an ounce:
The third,	———	an ounce.

Four rabbits were drowned in quickſilver, in the ſame manner; and when they were removed, we obtained from the lungs of

	Quickſilver.	*Frothy mucus.*
The firſt, -	two drachms,	ſix drachms:
The ſecond,	one drachm,	half an ounce:

And from the two laſt we got no quick-ſilver.

Hence

(*a*) By meaſure.

Hence it is evident, that the whole quantity of the fluid found in the lungs of drowned animals is inconſiderable, and that it is generally compoſed partly of the natural mucus of the lungs, and partly of the fluid which paſſes into them during the efforts to inſpire.

Since, then, the quantity of the fluid which enters into the lungs is ſo very inconſiderable, are we to ſuppoſe that it alone produces the changes which take place in conſequence of ſubmerſion?

If the quickſilver alone produced theſe changes in the animals of the laſt experiment, the ſame changes will be produced by introducing an equal quantity of any fluid into the lungs of a living animal, when it is not immerſed in water.

It was ſhown, in the laſt experiments, that the greateſt quantity of quickſilver which paſſed into the lungs of the cats, was five drachms. Let us ſuppoſe a quantity equal to the whole of the mucus and quickſilver obtained from the lungs, paſſed into them from without: if it occaſioned the death of the animal, we ſhall produce the ſame effect by introducing an equal quantity of water into the lungs of a ſimilar animal, whilſt the reſpiration is not otherwiſe interrupted.

Experiment IV.

I confined a cat in an erect poſture, and made a ſmall opening in the trachea by cutting out one of the cartilaginous rings. Through this opening I introduced two ounces of water into the lungs. The animal had immediately a difficulty of breath-

ing, and a feeble pulſe: but theſe ſymptoms were ſoon abated; and it lived ſeveral hours afterwards without much apparent inconvenience. At length I ſtrangled it, and found two ounces and a half of water in the lungs.

I introduced two ounces of water into the lungs of two other cats, in the ſame manner. The difficulty of breathing, and alteration of pulſe, were ſomewhat greater than in the firſt experiment; but in a few hours theſe complaints were abated: the animals were then ſtrangled, and four ounces of fluid were found in the lungs.

Here then, although a quantity of water be introduced into the lungs, greater than the whole quantity found in them in theſe experiments, yet it does not produce in the body thoſe changes that take place in drowning.

It follows, therefore, that the water which enters into the lungs of animals in drowning, is not the cauſe of the changes that take place in the body.

From theſe experiments we draw the following concluſions:

1°, A ſmall quantity of water commonly paſſes into the lungs in drowning.

2°, The water enters into the lungs during the efforts to inſpire, and, mixing with the pulmonary mucus, occaſions the frothy appearance mentioned by authors.

3°, The whole of this fluid in the lungs is not ſufficient to produce the changes that take place in drowning.

And hence it follows, *That the water produces all the changes that take place in drowning*, indirectly, *by excluding the atmoſpheric air from the lungs.*

To trace theſe changes to the excluſion of air, we muſt inquire into the particular effects of the air on the lungs in reſpiration, and the connexion of theſe effects with the different functions of the body: and when theſe are aſcertained, it will be eaſy to determine what changes muſt take place in conſequence of the privation of air.

The firſt and moſt obvious effect produced in the lungs by reſpiration, is an alteration in the volume of air they contain; and this muſt occaſion a proportional change in the degree of their dilatation, and conſequently in the form of the veſſels diſtributed upon them.

We proceed to inveſtigate theſe changes, and to trace their connexion with the other functions of the body.

SECTION

SECTION III.

To determine the mechanical Effects of the Air on the Lungs in Reſpiration.

TO obtain the object propoſed in this Section, we muſt firſt aſcertain the different quantities of air in expiration and in inſpiration, and the proportional dilatation of the lungs in each of theſe ſtates; and then endeavour to determine the effects of theſe different degrees of dilatation on the pulmonary veſſels, and on the current of the blood circulating through them.

Several writers have attempted to meaſure the quantity of air taken in by a ſingle

inſpiration; and ſome of them have delivered eſtimates of the proportional dilatation of the lungs, both in inſpiration and in expiration (*a*). Theſe eſtimates were in a great meaſure adopted by a celebrated phyſiologiſt; and he deduced many conſequences from them, to explain a variety of diſeaſes immediately connected with theſe mechanical changes (*b*): but the means employed to form theſe eſtimates appear to have been inſufficient; and the conſequences deduced from them are contradicted by ſeveral common appearances of the body: we ſhall therefore attempt to meaſure

---

(*a*) *Borelli* de Motu Animal. Lib. II.—*Jurin*, Differt. IV. Lib. IV.—*Hales*, Veget. Statics, Vol. II.—*Sauvage* de Reſpiratione difficili.—*Bernoulli*, Diſſert. de Reſpiratione.

(*b*) *Haller*, Element. Phyſiolog.

meaſure theſe quantities again, and to form our eſtimate from the reſult of the experiments:

And, firſt, to meaſure the quantity of air taken into the lungs after a complete expiration.

As every animal makes a full expiration immediately before death, the lungs in a dead body are in a ſtate of complete expiration: if, therefore, we can meaſure the quantity of air in the lungs of dead bodies, we ſhall determine the medium quantity in a ſtate of complete expiration. Now, it is generally known, that the lungs, in a ſound ſtate, are always contiguous to the containing parts of the thorax; and that all the containing parts of the thorax, except the diaphragm, are fixed after death: if, then, we fix the diaphragm of a dead body,

and make an opening through the external parts into the cavity of the thorax, the atmoſpheric air will paſs in by its own gravity, and, preſſing upon the external ſurface of the lungs, will force them to collapſe, and expel the air they contain; and that part of the cavity of the thorax which they before occupied, will be the meaſure of the volume of air expelled from them. If we now fill up this part of the cavity with water, it will give the quantity of air which was in the lungs after expiration.

Experiment I.

I procured a dead body of ordinary ſtature, and applied a cloſe compreſs upon the ſuperior part of the abdomen, to fix the diaphragm in its ſituation: then I made a ſmall opening into the cavity of the thorax on each ſide, and upon the moſt elevated part.

part. The lungs immediately collapſed; and conſequently the air which they contained was expelled. Water was next introduced at theſe openings, till the cavity was filled; and the contents of the water were 272 cubic inches.

The lungs of this body contained therefore 272 cubic inches of air in a ſtate of complete expiration.

The ſame experiment was repeated on two other bodies, nearly in the ſame circumſtances; and the lungs of the firſt, in a ſtate of complete expiration, contained 250 cubic inches of air, and the lungs of the ſecond 262 cubic inches.

The ſubjects of theſe experiments died from hanging; and I was not aware that there could be any objection to the experiment

ment on that account: but it afterwards occurred to me, that their lungs were not in a ſtate of expiration; becauſe perſons under the influence of fear often make a deep inſpiration, before the cord is paſſed round the trachea; and the preſſure of the cord becomes immediately ſo tight, that they are not able to expel the air again.

On this account I repeated the experiment on ſeveral adult ſubjects, who died a natural death. In ſome of them the lungs adhered to the ſides of the thorax, and did not collapſe completely, when the openings were made; but in four of them the lungs appeared to collapſe properly; and we had the following reſults:

The lungs of the firſt contained 120 cubic inches,
——— the ſecond 102
——— the third 90
——— the fourth 125

Theſe

Theſe experiments are ſufficient to ſhow, that the lungs contain a conſiderable quantity of air, even after complete expiration: but this quantity muſt vary in different ſubjects in proportion to the capacity of the thorax; it is therefore extremely difficult to eſtabliſh a medium. However, to purſue this inquiry, we ſhall for the preſent adopt the medium quantity of theſe latter experiments, and ſay that the lungs of the human ſubject contain 109 cubic inches of air after complete expiration.

We next proceed to meaſure the quantity of air taken into the lungs at an ordinary inſpiration.

This may be done by breathing from a veſſel which has only two tubular openings, one to be applied to the mouth, whilſt the other is immerſed in water. If we inſpire from

from the veſſel, under theſe circumſtances, a quantity of water will enter it, equal in volume to the quantity of air inſpired from it.

On this principle we contrived the machine A B C D E. The veſſel D contains ſeveral hundred cubic inches of air. This veſſel (which for the ſake of diſtinction I call pneumatic) ſuſpended in the balance A B, and brought to an equilibrium with the ſcale C; and the tube *a b c* being immerſed in water in the veſſel G; if a perſon inſpires from the tube E, a volume of water will enter the pneumatic veſſel through the tube *a b c*, equal to the volume of air inſpired from it by the tube E. The ſcale C will determine the weight of the water in the pneumatic veſſel; and this, by calculation, will give the number of cubic inches of water which entered the machine

at

at a ſingle inſpiration, and the number of cubic inches of water will give the number of cubic inches of air.

Experiment II.

An adult perſon of ordinary ſtature inſpired twice from the machine; imitating, as nearly as he could, an ordinary inſpiration.

In the firſt he took in 3 cubic inches of air;
In the ſecond $2\frac{1}{2}$ cubic inches.

Another perſon, of nearly the ſame ſtature, inſpired twice:

In the firſt he took in $3\frac{1}{5}$ cubic inches of air;
In the ſecond $2\frac{3}{4}$ cubic inches.

In theſe experiments there is a difference in the quantity of air taken into the lungs at a ſingle inſpiration, which we ſuſpected might

might ariſe from the attention of the mind in this new ſituation of breathing. To avoid this ſource of error, as much as poſſible, we determined that the ſame perſon ſhould inſpire regularly from the pneumatic veſſel for a minute or two, and expire alternately into the atmoſphere, numerating all the inſpirations; and that we ſhould then meaſure the water which paſſed into the veſſel during that time, and calculate the average quantity for each inſpiration.

Experiment III.

The two perſons employed in the laſt experiment inſpired from the pneumatic veſſel thirty times ſucceſſively, in the manner juſt deſcribed; and the average quantity of air taken in at a ſingle inſpiration, by the firſt perſon, was $2\frac{3}{4}$ cubic inches;

By the ſecond, $3\frac{1}{6}$.

It

It appears, then, that the quantity of air taken into the lungs at a ſingle inſpiration is very inconſiderable, when compared with what they contain after a complete expiration. This extraordinary difference was remarked with ſurpriſe by ſeveral judicious friends; and they expreſſed their fears that I might have been deceived. In conſequence of this, we repeated the ſecond experiment again, with ſtill more attention, and on a greater variety of ſubjects; and in all of them the average quantity of each inſpiration was nearly the ſame as in the preceding: but in the third experiment an anxiety was felt in the breaſt, before the limited number of inſpirations was finiſhed; and when the mouth was withdrawn from the tube, we obſerved that it was neceſſary to make a deep inſpiration. Theſe two circumſtances ſeemed to ſhow, that the quantity of air taken into the lungs from the

machine

machine had not been ſufficient for the purpoſes of reſpiration; and this deficiency in quantity muſt be attributed to ſome particular circumſtances of the experiment.

In all theſe experiments we attended to the *effort* made by the organs of reſpiration when the ordinary quantity of air is taken in from the atmoſphere; and we conſidered the force of this *effort* as the meaſure of an ordinary inſpiration (*a*), and endeavoured to copy it exactly when we inſpired from the machine: but we find that this is not ſufficient; becauſe the water muſt riſe into the

(*a*) Every one knows, that there is a conſiderable difference in the quantity of air taken into the lungs at an ordinary, and at a full inſpiration: if a perſon expires carefully, and then makes a full inſpiration, he will frequently take into his lungs upwards of 200 cubic inches of air at a ſingle effort.

A
B
C
E
b
a
c
D
G

the pneumatic veſſel contrary to its own gravity; and in order to overcome this additional reſiſtance, it will be neceſſary that the effort to inſpire from the machine be greater than the ordinary *effort* in the atmoſphere. And this has been the ſource of the miſtake.

Since, then, the effort in the atmoſphere is not the meaſure of a natural inſpiration from the machine, we muſt have recourſe to the ſenſation in the lungs. If we inſpire from the pneumatic veſſel ſeveral times ſucceſſively, as in the laſt experiment, and take in as much air at each time as to leave no uneaſineſs in the lungs during the inſpirations, nor any want of a greater quantity when the mouth is removed, we may conclude that the lungs have received as much air at each inſpiration as is required for the purpoſes of reſpiration.

Experiment IV.

Three perſons of ordinary ſtature inſpired from the pneumatic veſſel thirty times ſucceſſively, and took in as much air at each time as the ſenſations in the breaſt ſeemed to require. The average quantity of air taken into the lungs at a ſingle inſpiration by the firſt, was — 12 cubic inches;
By the ſecond — 14 cubic inches;
By the third — 11.

Hence it appears, that the quantity of air required for a ſingle inſpiration is greater than could be expected from the preceding experiments: but this alſo varies a little in different perſons; and it is equally difficult to eſtabliſh a medium for inſpiration, as for expiration. We ſhall however take the medium quantity here at 12 cubic inches.

But the air which paſſes from the pneumatic veſſel into the lungs, goes from a cool to a warmer temperature; it muſt therefore undergo a degree of expanſion as ſoon as it gets into the lungs, and conſequently occupy a greater ſpace than before. This degree of expanſion may be meaſured, by incloſing a given quantity of atmoſpheric air in a glaſs receiver, diſpoſed in ſuch a manner as to indicate the alteration of temperature, and the proportional expanſion, at the ſame time.

Experiment V.

I provided a cylindrical glaſs receiver, with a thermometer ſuſpended in the middle; I meaſured the quantity of water the receiver contained, and divided the whole capacity into ſeveral hundred parts, which were diſtinguiſhed by correſponding marks on the outſide: then I inverted it in water,

and introduced into it an hundred parts of atmoſpheric air at 69° of Fahrenheit, and applied heat to it gradually by means of warm water, until the thermometer in the inſide was raiſed to 98°: the volume of the whole was then increaſed $\frac{1}{6}$th. In ſeveral ſucceſſive repetitions the proportional expanſion was nearly the ſame.

If, then, we allow 12 cubic inches for a ſingle inſpiration, they will be increaſed to 14 cubic inches when they get into the lungs; therefore the volume of air before in the lungs receives an addition of 14 cubic inches by an ordinary inſpiration. But the volume of air in the lungs, before an inſpiration, was 109 cubic inches; hence it will be increaſed to 123 cubic inches; and the diſtention of the lungs muſt be changed in the ſame proportion: therefore the dilata-

tion

tion of the lungs after expiration is to their dilatation after inſpiration as 109 to 123 (*a*).

We next inquire into the effects of theſe different degrees of dilatation on the pulmonary veſſels, and on the current of the blood circulating through them.

Haller aſſerts, that the pulmonary veſſels are very much changed in the different ſtates of reſpiration; that they are conſiderably lengthened by inſpiration, and their angles and diameters ſo diſpoſed, as beſt to favour the circulation of the blood; but that they are greatly ſhortened by expiration, and their angles and diameters ſo much altered, as to produce a complete

 obſtruc-

(*a*) That is, as 4,7769 is to 4,9732; the difference being only ,1963; which is not even two tenths of an inch.

obſtruction to the paſſage of the blood through them.

" In inſpiratione," ſays he, " pulmo qui " nunquam pleuram deſerit, per eosdem " paſſus quibus pectus dilatatur, et ipſe in " utroque diametro latior nunc fit, et in " ſpatium majus, ſed ſui ſimile augetur. " Id augmentum varie eſtimatum eſt; quin- " tuplo per inſpirationem, pulmonem am- " pliorem fieri clariſſ. Sauvages conjecit, " et inde decuplo.

" Vaſa ergo ſanguinea omnis generis cum " adteńſis bronchiis neceſſario extenduntur, " et flexiones alternæ in quas ea vaſa in ſe- " ipſa retracta, in ſtatu pulmonis minimo " ſe reciperant, eæ nunc in rectitudinem " exporriguntur :——Porro quæ ſibi in- " cumbebant proxima, ea a mutuo con- " tactu diſcedunt, et anguli inter diviſiones

" vaſorum

" vaſorum majores fiunt, ſpatiaque adeo vi-
" cinis vaſis interponuntur.——Hinc in
" inſpiratione ſumma facilitas naſcitur ſan-
" guini de corde dextro exeunti.——In
" expiratione vero pulmo undique urgetur,
" et in multo minorem molem compri-
" mitur: vaſa ergo ſanguinea breviora
" quidem fiunt cum retractis bronchiis,
" eademq; anguſtiora nunc ſunt, ſiqui-
" dem pectus ſecundum tres ſuas dimen-
" ſiones arctatur.——Sanguis ergo quidem
" in pulmones undique comprimitur; et
" venoſus æqua vi preſſus, partim verſus
" arterioſum quidem reprimitur, eumque
" moratur aliquantum, partim verſus cor
" ſiniſtrum promovetur.——Quare in ex-
" piratione quam ponimus ſtabilem ſuper-
" eſſe, pulmonis pro ſanguine immeabilitas
" oritur, quam neque abſque palpitatione,
" et vitioſo conatu, demum omnino ullis
" ſuis viribus cor vincere queat."

Lib. VIII. Sect. 4.

But it appears, from theſe experiments, that the difference in the two ſtates of reſpiration is much leſs than Haller has repreſented; the changes produced on the pulmonary veſſels muſt conſequently be ſo likewiſe: the inferences he has drawn reſpecting the circulation of the pulmonary blood are therefore erroneous.

If we ſuppoſe the lungs dilated with the ordinary quantity of air in expiration (109 cubic inches), and then ſuppoſe 14 cubic inches more to be added, the dilatation of the lungs will be increaſed; but the increaſe will be uniform, and only in the proportion of 123 to 109; the pulmonary veſſels will be alſo extended uniformly in all directions (*a*), and their extenſion will be in the ſame

(*a*) To ſuppoſe, with Haller, that the angles of theſe veſſels are changed, although the form of the lungs continues the ſame, is contrary to one of the fundamental principles of geometry.

ſame ratio: ſince then there is no other change produced on the pulmonary veſſels by reſpiration, but a difference in the degree of extenſion, and ſince this is ſo ſmall, the alteration in the ſum of their diameters muſt be equally ſo; and if the blood circulates through them in one ſtate, it muſt alſo in the other: and hence it follows, that the blood circulates through the pulmonary veſſels in all the degrees of natural reſpiration.

But, notwithſtanding this concluſion, it may be ſtill ſuſpected that the pulmonary blood does not circulate with proper freedom in all the different ſtates of reſpiration; that, in the ſtate of expiration, the current may be ſo much retarded, as to occaſion an accumulation in the veſſels of the right ſide of the heart, ſufficient to bring on an interruption or ſuſpenſion of ſome of the

the other functions. If it be ſo, the ſame effects will be produced by introducing a quantity of any fluid into the cavity of the thorax, to force the lungs to collapſe, and expel ſo much air as will reduce their volume much below the degree of ordinary expiration. This experiment is frequently made in the human body by diſeaſe: a quantity of watery fluid gets into the cavity of the thorax between the containing parts and the lungs, occupying a very conſiderable ſpace, and reducing their volume much below the dilatation of ordinary expiration; and ſtill there is no ſuſpenſion of any of the other functions. Many examples of this diſeaſe have been recorded by different writers, where the fluid was taken away ſeveral times from the cavity of the thorax, during the life of the patient: and there is one in the Memoirs of the Academy of Surgery, where the Author expreſſes much

much ſurpriſe that the blood could circulate through the lungs, while ſuch a quantity of fluid was confined in the thorax.

" Après les ſymptômes ordinaires," ſays the Author, " les chirurgiens prononçoient, " que c'étoit un hydrothorax, & décident " ſur l'opération.

" Le malade étoit donc aſſis dans ſon lit, " le corps penché en avant, et ſoutenu par " pluſieurs aſſiſtans. Je lui fit la ponction " avec un trois-quart ordinaire. Le poin- " çon étant tiré, l'eau ſortit par la canule à " plein jet, et par des ſecouſſes qui répon- " doient aux mouvemens de la reſpiration. " Il en ſortit près de ſix pintes * d'une fluide. " Bientôt après, ſon pouls ſe ranimoit.— " Sept jours après, l'accumulation ſe faiſoit " encore;

(a) De France, *i. e.* 288 cubic inches.

" encore; & je tirai par la même opération
" encore cinque pintes."

" Dans ces cas, le poumon, fort écarté
" des parois de la poitrine, doit être pelo-
" tonné vers le centre, & réduit à un fort
" petit volume, & ſes véſicules très-rétré-
" cies.——C'eſt aſſez pour expliquer la
" difficulté de la reſpiration.

" J'ai obſervé que toutes les fois qu'on
" inſinuoit la ſonde de poitrine dans la ca-
" pacité, on l'introduiſoit à la longueur de
" quatre ou cinq pouces, ſans toucher ni
" rencontrer aucune partie intérieure; &
" c'eſt une choſe qui m'étonnoit toujours!"
Tom. II. p. 546.

I have frequently made a ſimilar experiment on ſeveral dogs, producing an artificial hydrothorax by introducing as much water through an oblique opening of the intercoſtal

intercoſtal muſcles into the thorax, as nearly filled one third of the whole cavity, cloſing the orifice afterwards. In all of them it brought on a conſiderable difficulty of breathing, but no other apparent inconvenience.

In theſe examples the volume of the lungs muſt have been conſiderably reduced, and the greateſt quantity of air they were capable of containing much leſs than the ordinary quantity in an healthy expiration; and ſtill the blood continued to circulate through the pulmonary veſſels in ſufficient quantity to keep up the action of the left ventricle of the heart, and the other functions of the body.

If, therefore, the blood circulates through the pulmonary veſſels with this freedom when the volume of the lungs is ſo much diminiſhed, it muſt certainly circulate through them

them with equal eaſe in expiration when the volume of the lungs is much greater: hence it follows, that the blood circulates through the lungs in expiration with ſufficient freedom to keep up the health of the ſyſtem.

From all theſe experiments we draw the following concluſions:

1°, The lungs contain 109 cubic inches of air after a complete expiration; and this quantity receives an addition of 14 cubic inches by inſpiration.

2°, The dilatation of the lungs after expiration is to their dilatation after inſpiration as 109 to 123.

3°, The blood circulates through the pulmonary veſſels in all the degrees of natural reſpiration.

4°, The

4°, The circulation through them after expiration is ſufficiently free to keep up the health of the ſyſtem.

And hence it follows, *that the dilatation of the lungs is not the final cauſe of reſpiration.*

Another effect produced in the lungs by reſpiration, is a change in the chymical qualities of the air they contain. We proceed to inquire into the particular nature of this change, and its connexion with the other functions of the body.

SECTION

SECTION IV.

To determine the Chymical Effects of the Air on the Lungs in Reſpiration.

IT has been long ſuſpected by philoſophers of the firſt character (*a*), that the air which we breathe undergoes ſome chymical changes in the lungs; and various conjectures have been propoſed concerning them, by different writers, at different times; but nothing more could be expected from the moſt penetrating mind, until chymiſtry put on the form of a ſcience: from that period the clouds of hypotheſis have been diſpelled, and the dawn of truth begins to appear. We ſhall not enter

(*a*) Ariſtotle, Sir Iſaac Newton, &c.

enter into a detail of theſe different conjectures, nor of the progreſſive diſcovery of the facts connected with the ſubject; but rather endeavour to deſcribe the conſtituent parts of atmoſpheric air, as far as they are now known, and then inveſtigate the particular changes they undergo by reſpiration.

When atmoſpheric air is analyſed with the ordinary chymical teſts, it is found to be compoſed of phlogiſticated air, dephlogiſticated air, and fixed air. If any given quantity of atmoſpheric air (ſuppoſe 100 parts) be accurately analyſed in this manner, it is generally found to contain nearly two thirds of phlogiſticated air, one third of dephlogiſticated air, and a very ſmall quantity of fixed air: but the proportions of theſe airs are generally different in different parts of the atmoſphere, and ſometimes no fixed air can be found.

If 100 parts of analyſed atmoſpheric air be inſpired, and expired again into a receiver, it is found to have undergone a change in the proportion of its conſtituent parts: the quantity of dephlogiſticated air is diminiſhed, the quantity of fixed air increaſed, and the phlogiſticated air remains the ſame.

A celebrated chymiſt has propoſed to aſcertain the changes (*a*) which theſe airs undergo by a ſingle reſpiration (*b*): but the reſults of ſuch experiments are ſubject to ſome variations from the ſtate of the body, and from the duration of the reſpiration. Notwithſtanding theſe difficulties, I made ſeveral experiments on myſelf, to aſcertain the particular degree of theſe changes; and although there was always a little difference in

(*a*) Monſ. Lavoiſier.

(*b*) One inſpiration and one expiration.

in the reſults, yet by frequent repetition they became inconſiderable.

Firſt, I aſcertained the proportion of theſe airs in 12 cubic inches of atmoſpheric air; then I inſpired an equal volume of the ſame air, expiring it into a glaſs receiver, and analyſed the whole quantity. This was repeated ſeveral times, and the medium quantity was as follows:

The volume of air taken into the lungs at a ſingle inſpiration contained,	*Parts.*	The volume of air expelled from the lungs by the next ſucceeding expiration contained (*a*),	*Parts.*
Phlogiſticated air	80	Phlogiſticated air	80
Dephlogiſticated air	18	Dephlogiſticated air	5
Fixed air - - -	2	Fixed air - - -	13
	100		98

(*a*) In all theſe attempts I endeavoured to imitate the natural expirations; but the volume of air ex-

It appears, then, that the diminution of dephlogiſticated air, and the increaſe of fixed air, in a ſingle reſpiration, is conſiderable.

Let us next inquire if this diminution of the one, and increaſe of the other, be uniform and conſtant in the ſame volume of air ſeveral times reſpired: and, firſt, the diminution of the dephlogiſticated air.

This may be done by breathing a quantity of air ſeveral times from a glaſs receiver inverted in water, and by mixing a ſmall quantity of this air, after every expiration, with an equal quantity of nitrous air in the eudeometer of Fontana: the quantity of dephlo-

---

pelled from the lungs was never equal to the volume of air taken in; ſometimes there was a diminution of $\frac{1}{50}$, and ſometimes $\frac{1}{60}$. This diminution was obſerved long ago by Boyle and Muſſenbrock.

dephlogiſticated air will then be indicated by the diminution of volume in the eudeometer.

I paſſed 12 cubic inches of atmoſpheric air into a glaſs receiver inverted in water, and put a meaſure of it into the eudeometer, and it occupied 100 parts; then I added an equal meaſure of nitrous air, and the whole volume of 200 parts was diminiſhed to — — — 144

Then I inſpired the whole of the volume from the receiver, and expired it in the uſual time; and on trying an equal portion of it in the eudeometer, the 200 parts were diminiſhed to — 158

After the ſecond expiration they were diminiſhed to — — 163

After the third, to — — 167

After the fourth, to — — 170

After the fifth, to — — 171

We might alſo determine whether the addition of fixed air be conſtant and uniform in ſeveral ſucceſſive reſpirations, by breathing a given volume of air in the ſame manner from an inverted receiver, and paſſing a ſmall quantity of it through lime-water after every expiration: but this would require great labour and minute attention; and ſince we know the quantity of fixed air added by a ſingle expiration, it is eaſy to determine whether there be any additions made to it afterward, by breathing the ſame air ſeveral times, and, after the laſt expiration, examining it with lime-water, and comparing the whole quantity of fixed air with the known quantity of a ſingle reſpiration.

I incloſed 12 cubic inches of air in an inverted receiver, and breathed it through a glaſs tube ſix times in ſucceſſion: on being examined with lime-water after the laſt

expiration

expiration it contained 15 parts of fixed air. The ſame experiment was repeated, and the quantity of fixed air was 13 parts.

The diminution of dephlogiſticated air, and the increaſe of fixed air, is therefore conſtant and ſucceſſive in the ſame quantity of air frequently reſpired: but the changes in the ſucceſſive reſpirations bear no proportion to the changes in the firſt. Since, however, theſe changes are conſtant and uniform, they muſt be connected with ſome correſponding changes in the lungs equally conſtant and uniform; and there is no ſubſtance in the lungs where we can expect to find ſuch correſponding changes, except the blood which circulates through them.

Lower obſerved long ago in living animals, that the blood from a wound in the trunk of the pulmonary vein was florid;

and knowing before that the blood entering into the lungs by the pulmonary artery is black, he concluded that it acquired this florid colour by paſſing through the lungs; and finding afterwards that, when the animal ceaſed to breathe, the blood from the wound in the pulmonary vein was black, he attributed the florid colour to the action of the air in reſpiration (*a*). This opinion has been mentioned frequently ſince by different authors, and ſeems now to be generally believed.

To examine the fact with particular attention, I procured ſeveral large dogs, removed the ſternum, and expoſed the trunks of the pulmonary veins and arteries ſo as to allow me to diſtinguiſh accurately the colour of

(*a*) Tractatus de Corde, p. 185.

of the blood paſſing through them. Then I inflated the lungs with a pair of bellows (after the deſcription of (*a*) Veſalius), imitating the natural reſpiration, and kept the animal alive by this proceſs for a conſiderable length of time. In theſe experiments it was obſerved, that, during the inflation, the blood in the trunks of the pulmonary artery was black, but in the trunks of the pulmonary veins it was florid: and when the inflation was intermitted for a minute, the blood in the trunks of the pulmonary vein became gradually black, like that in the arteries.

In ſome of theſe animals I divided the trunks of the humoral artery and vein; and during the inflation the blood from the artery

(*a*) Veſalius de Corporis Humani Fabrica, Lib. VI. Cap. xix. p. 572.

artery was florid; but, on intermitting the inflation, it became gradually black, like the blood from the vein.

I alſo examined theſe appearances in the toad and the lizard, whoſe lungs conſiſt of only a tranſparent bladder, with blood veſſels ſo thin that the colour of the circulating blood may be eaſily diſtinguiſhed through them.

I inflated the lungs of theſe animals ſeveral times, and emptied them again by gentle preſſure, imitating by this method the reſpiration of the more perfect animals; and in all the examples, when the atmoſpheric air paſſed into the lungs, the blood in the pulmonary veſſels became gradually florid; but when they were emptied, it became gradually black: to this may be added the familiar circumſtance in blood-letting,

letting, the dark-coloured blood becoming florid after expoſure to the air.

All theſe facts ſeem to confirm the opinion of Lower, that the blood acquires a florid colour in paſſing through the lungs; and that this colour is produced by the chymical action of the air.

We next inquire by what part of the reſpired air this change of colour is produced, and what particular chymical proceſs takes place at the time.

Does it ariſe from the addition of fixed air ſeparated from the blood in paſſing through the lungs, or from the chymical action of the phlogiſticated or the dephlogiſticated air?

If the florid colour ariſes from the ſeparation of fixed air in its entire ſtate from the

the blood, then florid blood expoſed to a volume of fixed air in a cloſe veſſel muſt become black alſo.

I introduced four ounces of florid blood, freſh drawn, into a glaſs receiver containing fixed air, and I confined it there a conſiderable time; but it did not become black, nor undergo any ſenſible change. I then received ſome florid blood from the carotid artery of a ſheep into a phial filled with fixed air; but ſtill the florid colour was not altered: therefore the change of colour in reſpiration does not ariſe from the ſeparation of fixed air in its entire ſtate from the blood.

Nor can it be attributed to the chymical action of the phlogiſticated air; for it is generally known, that black blood, freſh drawn, expoſed to phlogiſticated air in a cloſe veſſel, undergoes no change of colour.

But

But it has been often aſſerted, that black blood freſh drawn, and expoſed to dephlogiſticated air, becomes florid.

To aſcertain the truth of this aſſertion, I incloſed a quantity of dephlogiſticated air in a glaſs receiver inverted in quickſilver, and introduced into it four ounces of blood freſh drawn from the jugular vein of a ſheep: the blood became inſtantly very florid, and the quickſilver ſeemed to aſcend a little in the receiver. To aſcertain this latter circumſtance, I repeated the experiment three or four times: the change of colour was always very ſudden, and after ſeveral minutes the quickſilver aſcended two or three lines. It is evident, then, that dephlogiſticated air changes the colour of black blood, and a ſmall portion of the air diſappears in the proceſs: but, as the changes in theſe experiments are ſimilar to thoſe in reſpiration,

reſpiration, it might be inferred, that dephlogiſticated air produces the florid colour in both examples.

To ſatisfy myſelf of this, I inflated the lungs of ſeveral kittens with dephlogiſticated air, after the ſternum was removed; and the blood in all the pulmonary veins became immediately very florid.

Hence it is evident, that the florid colour acquired by the blood in reſpiration is produced by dephlogiſticated air. But it may be aſked, by what means the air is applied to the blood in reſpiration? whether by means of the abſorbents, or by the force of chymical attraction?

If it were taken in by the abſorbents, it muſt paſs directly to the right ſide of the heart, and change the colour of the blood there; which does not happen.

It

It has been ſhewn by Dr. Prieſtley, that atmoſpheric air will change the colour of blood through the coats of a bladder; but there are no direct proofs that it will produce the ſame effect through the coats of the veſſels in a living animal.

To determine this, I diſſected the cellular membrane from the ſmall veins in the neck of ſeveral rabbits, and confined the blood in them by ligatures; then I conducted a ſmall ſtream of dephlogiſticated air to the coats of the veſſels: in ſome of them the blood became a little florid; but in others there was no diſtinct change, although the ſtream of air was conducted for two minutes.

In theſe inſtances, however, where it took place, ſomething muſt have pervaded the coats of the veſſels; and this makes it highly

highly probable, that, when the dephlogiſticated air produces the change of colour in the blood, ſomething pervades the coats of the pulmonary veſſels by the force of chymical attraction.

But what it is that pervades the veſſels, is not yet known: whether ſome principle ſeparated from the blood be combined with the dephlogiſticated air, to form fixed air; or whether the dephlogiſticated air be decompoſed, and a part of it paſſes into the blood, while the other part remains behind in the form of fixed air; or, laſtly, whether the dephlogiſticated air enters into the blood in its entire ſtate, whilſt the fixed air is ſeparated from the veſſels.

The greater number of facts in chymiſtry ſeem to favour the firſt ſuppoſition; but yet they only make it probable; and more than

than probability cannot be expected, until the nature of these airs be better understood.

But, whatever solution future experiments may furnish, this general fact will remain unaltered; *viz.* That the change of colour which the blood undergoes in passing through the lungs, is occasioned by the chymical action of the dephlogisticated air of the atmosphere; and that, in consequence of this, fixed air is received.

To proceed in the inquiry, we endeavour to trace the connexion of this change in the pulmonary blood with the other functions of the body.

It is generally known, that when an animal breathes the same air several times, his pulse becomes slower, till at length it ceases,

and all the other functions are ſuſpended; and it is alſo known, that when reſpiration is obſtructed, ſymptoms very ſimilar are produced. How are theſe facts connected together?

It has been ſhown already, that, when the ſame air is breathed ſeveral times, or when it is retained in the lungs longer than uſual, there is a gradual diminution of dephlogiſticated air, and an increaſe of fixed air. Theſe ſymptoms then muſt ariſe from one of theſe circumſtances; either from the noxious quality of the additional fixed air, or from the want of the ſalutary quality of the abſent dephlogiſticated air: but the additional fixed air exerts no noxious quality in the lungs; becauſe it may be breathed in a much greater quantity without any inconvenience when mixed with atmoſpheric air: they muſt then be attributed to the

gradual

gradual diminution of the dephlogiſticated air.

When the dephlogiſticated air is thus diminiſhed, the ordinary change of colour which the blood undergoes in the lungs will be alſo diminiſhed, till at length it will paſs through the pulmonary veins with the ſame black colour as when it entered into the arteries.

This has been already in a great meaſure demonſtrated in the examples of artificial inflation; and it may be ſeen ſtill better in the toad and the lizard, where the lungs may be expoſed a long time without deſtroying the life of the animal.

I forced a conſiderable quantity of air into the lungs of a ſmall dog, whoſe ſternum had been removed, and confined it there by a tight ligature round the trachea: the

blood, continuing to circulate through the lungs in this ſtate, began immediately to put on a ſhade of brown in the trunks of the pulmonary veins; and in leſs than two minutes it became very black.

With the ſame view I provided a large toad, and expoſed his lungs on both ſides; and while they were filled with air, I immerſed him in a ſmall glaſs receiver containing water. When he was firſt put into the water, the blood circulating through his lungs was florid: when he had continued in the water twenty minutes, the lungs ſtill filled with air, the blood in all the pulmonary veſſels became gradually dark-coloured, till at length it was black. This was repeated ſeveral times with the ſame animal, and once or twice alſo with lizards; and in all the inſtances where they retained the air in their lungs a long time after

after immerſion, the pulmonary blood became gradually black.

It follows, therefore, that when the dephlogiſticated air is gradually diminiſhed, the blood paſſing through the veſſels of the lungs does not undergo the changes of colour which take place in ordinary reſpiration; and that the ſymptoms which follow obſtructed reſpiration muſt be attributed to this particular quality of the blood. But by what means it produces theſe ſymptoms, we next inquire.

The firſt ſuppoſition is, that it exerts ſome noxious quality on the nerves of the lungs, which is communicated by them to the brain.

If it operates in this manner, the ſame ſymptoms will not be produced by ob-

ſtructed reſpiration, when the nerves diſtributed on the lungs are ſo divided that their communication with the brain is intercepted.

To aſcertain this, I provided a ſmall dog, and divided the trunks of the par vagum and great intercoſtal nerves on each ſide of the neck about an inch below the larynx: the ſkin was then ſewed up, and the animal appeared to ſuffer no other inconvenience than a laborious reſpiration. The next day I put him under a glaſs bell inverted, and filled with atmoſpheric air. When he had continued there ſeveral minutes, the reſpiration became difficult; and ſoon after he fell down without any ſign of life. I divided the nerves of another dog in the ſame manner; and the day following I paſſed a ligature round the trachea, and obſtructed the reſpiration: ſoon afterward he fell down without any ſign of life.

It appears, then, that the black blood produces the ſame ſymptoms when the nerves of the lungs have no immediate communication with the brain; and hence, in the caſes of obſtructed reſpiration, it can exert no ſuch noxious quality on the brain by the mediation of the nerves.

From the lungs this black blood paſſes immediately into the ſinus venoſus and left auricle of the heart. What changes does it produce there?

The only ſenſible change it can produce in the heart, is in its contractions; and theſe may be eaſily obſerved by inflating the lungs, when the ſternum is removed, and the pericardium opened in ſuch a manner that the motions of the auricles and ventricles may be diſtinctly perceived.

I made theſe experiments with all the circumſtances here mentioned; and in the proceſs of inflation I attended carefully to the changes in the colour of the blood, and in the correſponding contractions in the left auricle and ventricle of the heart; and in all the examples, I obſerved that when the blood which paſſed into the left auricle was florid, the auricle and ventricle contracted ſtrongly, and the circulation went on as in health; but when the blood began to put on a ſhade of brown, the contractions were diminiſhed; and when it was black, the contractions ceaſed, although the auricle was diſtended with blood; and as the contractions ceaſed, the functions of the body were ſuſpended; but as ſoon as the florid colour began to be reſtored, the auricle and ventricle reſumed their contractions, and they gradually recovered their natural ſtate; and all the other functions returned.

In

In theſe examples the contractions of the left auricle and ventricle are immediately affected by the quality of the blood (*a*) paſsing into them; for when they ceaſe, the auricle is filled with black blood: but notwithſtanding theſe facts, to ſuch as have particular

---

(*a*) This explanation has been objected to by ſome perſons, on very reſpectable authority. It has been ſaid that the heart reſumes its contractions at the firſt inflation; and, as the blood in its cavity cannot be ſuppoſed to be changed ſo ſoon, the renewal of the natural contractions muſt ariſe from ſome other cauſe. But theſe two circumſtances are only aſſertions, which have not yet been demonſtrated. Beſides, ſome contractile motion may be produced in the heart by the agitation it ſuffers from the firſt diſtention of the lungs, in the ſame manner as feeble contractions are produced in the hearts of amphibious animals out of the body by agitation, or gentle compreſſion; but theſe motions are not ſo ſtrong as the natural contractions, and they ought to be carefully diſtinguiſhed from them.

particular opinions about the manner in which the blood acts upon the heart, it may not appear clear that these alterations in the contractions arose from the quality of the blood alone. This difficulty, however, may be removed by attending to similar experiments in the amphibious animals (*a*), where

---

(*a*) Some respectable writers have employed the word *sympathy*, to express or explain the connexion between the heart and lungs. When the lungs are inflated, the heart moves, they say, by sympathy; but, as they have not defined the sense in which the term is here employed, no one can judge of the propriety of their reasoning. If by sympathy they mean here a separate principle or quality that is supposed to lie hid in the body, it is only a particular name for one of the occult qualities of the peripatetic school, which cannot be proved to exist; and, as they convey no information to the mind, they have been long since banished from all chaste philosophy.

where the heart has only one auricle and ventricle, where the pulmonary artery is a ſmall

---

If the term be intended to expreſs a mechanical cauſe, to aſſert that the motion of the lungs in reſpiration keeps up the natural contractions of the heart mechanically, the aſſertion is not ſupported by facts: for, if it were ſo, the motion of the lungs would be alone ſufficient to keep up the contractions of the heart, and any kind of aërial fluid would be then equally effectual in reſpiration; and whenever the motion of the lungs ceaſed for a while, the contractions of the heart would always ceaſe alſo: but there are ſeveral kinds of aërial fluids which are not ſufficient for the purpoſes of reſpiration; for when animals breathe them ſeparately, the contractions of the heart ceaſe, even while the reſpiration continues; and when the amphibious animals are immerſed in water, the motion of the lungs ceaſes, yet the natural contractions of the heart continue upwards of an hour afterward; which could not happen, if the motion of the lungs occaſioned theſe contractions mechanically.

But

ſmall branch from the aorta, and the pulmonary vein proportionally ſmall empties itſelf into the ſinus venoſus and auricle along with the vena cava aſcendens, which carries the principal part of the blood. Here the quantity of blood brought by the vena cava would be ſufficient to keep up the action of the heart, independent of the pulmonary circulation, if quantity alone were

---

But probably the term is uſed here in its original and more confined ſignification; *i. e.* to expreſs the co-exiſtence of effects, or the conſtancy with which one change in the body follows or accompanies another, without any regard to the efficient cauſe of either, or to the manner or probability of their connexion. In this ſenſe, as it expreſſes only the fact, no one can object to the uſe of it: but I cannot with propriety employ the word in this inquiry, as my object is to trace the manner of this connexion between the lungs and the heart, and to fill up the chaſm by inveſtigating their proper cauſes.

were required; and the coats of the ſinus venoſus and auricle, as well as thoſe of the blood veſſels, are almoſt tranſparent: the lungs alſo contain a quantity of air ſufficient to furniſh the neceſſary chymical changes to the pulmonary blood for a conſiderable time without any communication with the atmoſphere; ſo that the alterations which take place in the colour of the blood, and in the motions of the heart, in conſequence of obſtructed reſpiration, are more gradual and diſtinct than in the animals with double hearts, in which all the blood paſſes through the lungs.

I confined a large living toad on a plate of metal, with his belly upwards; then I removed a part of the ſternum, and his heart and lungs were expoſed to view. The lungs were then filled with air; the blood in the pulmonary veins was florid,

and

and the heart contracted 44 times in a minute. In this ſtate he was immerſed in a ſmall quantity of tranſparent water, where the alterations in the colour of the blood, and in the contractions of the heart, could be accurately diſtinguiſhed. When he had remained in the water 15 minutes, the blood in the lungs began to put on a dark colour, and the contractions of the heart were diminiſhed to 30. In 15 minutes more the dark colour of the blood was increaſed, and the contractions of the heart were 18. The animal now made ſeveral ſtruggles to relieve itſelf, and threw ſome air out of its lungs; but the pulmonary blood becoming ſtill more dark coloured, the contractions of the heart were diminiſhed ſtill further, and in 40 minutes more they ceaſed; although the ſinus venoſus and auricle, and the trunk of the vena cava, were filled with black blood. The animal

was

was now removed from the water, without any ſigns of life; but before the expiration of two minutes he opened his mouth, and took a large quantity of freſh air into his lungs. Soon after, he emptied them almoſt entirely; and this was repeated ſeveral times. During the proceſs, the blood in the pulmonary veins began to be florid, and the heart to renew its contractions; and in 15 minutes from the firſt inflation the contractions of the heart were 35, all the functions were recovered, and he walked about without any expreſſions of uneaſineſs.

This experiment was repeated ſeveral times on the ſame toad; and ſometimes, when he did not fill his lungs, after being removed from the water, we injected ſome air into them with a blow-pipe, and preſſed it out afterward, in imitation of the example

example he had given us; and by theſe means we renewed the contractions of the heart ſeveral times. But at length he was removed from the water, and ſuffered to remain an hour before freſh air was injected into his lungs. Soon after it was injected, the blood in the pulmonary veins became florid; but the heart did not again renew its contractions.

Theſe circumſtances were repeated afterward in the lizard; and in all the examples the contractions of the heart were diminiſhed in frequency, in proportion as the blood from the lungs became dark coloured; and they were renewed, when it became florid, in the ſame manner as in the experiment with the toad.

In all theſe examples the quantity of blood which came to the heart was fully ſufficient

ſufficient to keep up its contractions; and ſtill they were gradually diminiſhed in proportion as the pulmonary blood became darker; and when it was black, they ceaſed entirely. Theſe alterations, therefore, in the heart's motion, muſt ariſe from the quality of the blood only.

But it may be queſtioned, by what means the quality of the blood can diminiſh the motion of the heart? It muſt either exert ſome noxious power on the heart itſelf, or it muſt be an inſufficient ſtimulus to excite its contractions.

If it exerted a noxious power upon the heart itſelf, it muſt diminiſh or deſtroy the faculty of contraction (*a*); and if it diminiſhed or deſtroyed the faculty of contrac-

(*a*) By "faculty of contraction in the heart," I mean that quality by which it is diſpoſed to propel the blood through the circulating ſyſtem.

tion, the heart would not contract again when thoſe means are applied which are neceſſary to produce the contractions: but in all theſe experiments, where the heart ceaſed to contract when the blood which paſſed into it was black, as ſoon as ſome air had been received into the lungs to change a part of this blood to a florid colour, the contractions of the heart were renewed, and ſoon returned to their natural ſtate.

Therefore this black blood exerts no noxious power upon the heart itſelf; and we muſt conclude that, in all theſe caſes of obſtructed reſpiration, the heart ceaſed to contract, becauſe the blood which paſſed into it was an inſufficient ſtimulus (*a*). And

(*a*) This concluſion may perhaps, at firſt, appear ſingular; as the ſame black blood is a ſufficient ſtimulus

And hence it follows, *That the chymical change which the blood undergoes in the lungs by*

ſtimulus to the right auricle and ventricle; becauſe it is expelled from them juſt before, when it enters into the lungs: and if it be a ſufficient ſtimulus to excite the contractions of the heart on the right ſide, why not on the left alſo?

But it muſt be remembered, that the two ſides of the heart do not reſemble each other exactly in all their qualities: there is a conſiderable difference between them, *both in reſpect to the quantity of muſcular fibre, and the facility of being excited to contraction*; and this alone is ſufficient to diſarm the objection.

But, even if there were no ſuch difference, the inſtance is not peculiar to the heart; there are ſeveral examples in the animal body, where muſcles of a ſimilar ſtructure are not excited to contraction by the ſame or a ſimilar power: ſome of the muſcles are thrown into contraction by the will; ſome, by particular conceptions of the mind; and ſome, by chymical ſtimuli: yet none of theſe different powers will produce a perfect contraction of thoſe muſcles

by reſpiration, gives it a ſtimulating quality, by which it is fitted to excite the left auricle and ventricle to contraction.

From all theſe experiments we draw the following concluſions:

1ſt, A quantity of dephlogiſticated air is ſeparated from the atmoſpheric air in the lungs by reſpiration, and a quantity of fixed air is added to it.

2dly, The dephlogiſticated air exerts a chymical action on the pulmonary blood; in conſequence of which it acquires a florid colour.

3dly, In

---

to which they are not adapted by nature. Objections of this kind, therefore, do not apply immediately to our concluſions, but rather to the general law in animal bodies, which muſt be regarded at preſent as an *ultimate fact*.

3dly, In ordinary reſpiration this florid colour is ſeen diſtinctly as the blood paſſes into the left auricle; and the heart contracts then with its natural force and frequency.

4thly, When reſpiration is obſtructed, the florid colour is gradually diminiſhed, and the contractions of the left auricle and ventricle ſoon ceaſe.

5thly, This ceſſation of contraction ariſes from a defect of a ſtimulating quality in the blood itſelf.

And hence it follows,

That the chymical quality which the blood acquires in paſſing through the lungs, is neceſſary to keep up the action of the heart, and, conſequently, the health of the body.

SECTION V.

To determine the Nature of the Diſeaſe produced by Submerſion.

IT has been ſhown, in the Firſt Section, that animals confined in water throw out ſmall quantities of air, and then endeavour to take ſome in from the atmoſphere. By theſe efforts a portion of the ſurrounding fluid paſſes into their mouths, and often deſcends into the lungs; but the quantity is not ſufficient to produce the ſymptoms which afterward appear: (ſee the Experiments in the Second Section:) in the cavity of the lungs it mixes with the air, and increaſes the dilatation of the air-cells; in conſequence of which the lungs are in a middle

middle ſtate of dilatation; that is, between expiration and inſpiration: and in this ſtate the blood circulates through the pulmonary veſſels with ſufficient freedom to keep up the health of the ſyſtem; (ſee the Concluſions in the Third Section;) therefore the ſymptoms are not produced by an obſtruction of the circulation through the lungs.

From the ſituation of the animal, the air and water are confined in the lungs; and the dephlogiſticated air which it contains is gradually conſumed; and conſequently the blood paſſing through the pulmonary veſſels receives leſs and leſs of its florid colour, and the contractions of the heart become proportionally ſlower, until they ceaſe entirely (ſee the Experiments and Concluſions of the Fourth Section), although the faculty of contraction ſtill remains.

It appears, then, that the ceſſation of the heart's motion may be fully accounted for from the action of the water preventing the entrance of the air into the lungs.

Let us next inquire, if the other particular ſymptoms (ſee the Firſt Section) can be traced to the obſtruction of reſpiration, and to the conſequent ceſſation of the heart, as their proper cauſe.

In proportion as the colour of the blood paſſing through the lungs is darker, the contractions of the left auricle and ventricle, and the *correſponding pulſations of the arteries, become weaker*, and the current of the blood ſlower; and whilſt the blood moves ſlowly in the larger trunks, it begins to ſtagnate in the ſmaller branches of the arteries and veins, where the reſiſtance to its paſſage is greateſt. At length, when the

pulmonary

pulmonary blood is no longer fitted to excite the ſinus venoſus and auricle to contraction, *they receive it into their cavity, and remain at reſt.* As ſoon as they ceaſe to contract, and propel the blood to the head, *all the intellectual operations ceaſe* (*a*), *ſenſation and voluntary motion are ſuſpended, and the external ſigns of life diſappear*; and the black blood remaining at reſt in the arteries, and particularly in the ſmaller branches

(*a*) Whatever may be the efficient cauſe of the intellectual operations, ſenſation, &c. the circulation of the blood through the brain is an indiſpenſable condition for them in all the more perfect animals. This is proved by the familiar examples of fainting from ſudden or great loſſes of blood; where, as ſoon as the motions of the heart can be perceived to ceaſe, conſciouſneſs, and all the other operations attributed to the mind, diſappear; and when the action of the heart is reſtored, they all return again.

branches of the arteries and veins, occaſions *the blue colour upon different parts of the body* (*a*), *but eſpecially about the face and lips*,

---

(*a*) It appears from the diſſection (ſee Sect. V.) that this particular blue colour of the face, &c. ariſes from the preſence of the black blood in the ſmaller branches of the arteries and veins; and it is ſtill further confirmed by the following remarkable caſe in the Obſervationes Anatomicæ of Sandifort, of the authenticity of which I have abundant confirmation from living teſtimony. The ſubject is a boy born in 1764.

"In the ſecond year of his age the nails of his fingers were obſerved to become blue; but this blueneſs often diſappeared, and returned again, for the ſpace of a year, when a general languor came on, and ſome livid ſpots were obſerved on his face, which increaſed very much by exerciſe, till ſoon after the whole face became blue on the ſmalleſt exertion of the body, and particularly the lips and tongue. Towards the latter end of the year he perceived

lips, where the number of ſuperficial veſſels is moſt conſiderable. After the left auricle and

---

perceived an anxiety about his breaſt, and complained of a general coldneſs of the body, which was not relieved by the application of external heat. Blood-letting relieved the anxiety in the breaſt: his blood was very black, and did not ſeparate properly into ſerum and craſſamentum. In the third year he perceived frequent palpitations of the heart, for which the cold bath and exerciſe were recommended; but they ſeemed to aggravate his complaints. Theſe ſymptoms continued ſtationary until the 10th year, when they were conſiderably increaſed, and he had a ſpitting of blood.

"In the 11th year he perceived an anxiety in his breaſt upon the ſlighteſt motion of the body, and he frequently fainted: the face alſo ſeemed to be a little ſwelled, and the blue colour was much increaſed. At length his legs became œdematous, and he died. On opening the thorax, it was found that the aorta took its origin from both the ventricles of the heart; one and a half of the valvulæ ſemilunares were

and ventricle have ceaſed to contract, the right auricle and ventricle are ſtill expoſed to the action of thoſe means which naturally excite them to contraction, *and they continue to contract for ſeveral minutes*, and propel the black blood into the pulmonary arteries: this occaſions an accumulation in the pulmonary veſſels, and a livid colour on the lungs: but from the reſiſtance to the entrance of the blood into the pulmonary arteries, and from the want of the ſynchronic aſſiſtance of the left ventricle, the contractions of the right become gradually more feeble, until at length they ceaſe; and the right auricle, being ſoon after greatly diſtended

---

were extended over the right ventricle, and one and a half over the left ventricle; ſo that half the quantity of blood which paſſed into the aorta was always black, not having paſſed through the lungs to undergo the alteration of colour."

diſtended with blood, ceaſes to contract alſo; yet the faculty of contraction ſtill remains.

Thus we have traced the connexion of the ſymptoms, and the conſequent ceſſation of the heart, to the obſtruction of reſpiration, as to their *proper cauſe*. It remains only now to aſcertain the name of the diſeaſe, and the place it ſhould have in noſology.

As the gradual diminution of the pulſe is a conſtant ſymptom of this diſeaſe, it was firſt called Syncope (*a*): but, from ſome peculiarities afterwards obſerved, phyſicians thought proper to diſtinguiſh it from the

(*a*) Syncope. Motus cordis imminutus, vel aliquamdiu quieſcens. Noſol. Cullen. Genus 64.

the milder kinds of Syncope, and called it Aſphyxia (*a*); and this name has been generally retained. But another difficulty aroſe about the place it ſhould have in noſology; and, on account of the obſcurity of its nature, it was for ſome time excluded from every ſyſtem. At length it appeared probable, from the general maſs of obſervations and experiments, that the diminiſhed action of the heart and arteries aroſe from a morbid ſtate of the brain, occaſioned by the preſſure of ſome blood. In conſequence of this, the primary affection was called Apoplexy, and the diminiſhed action of the heart only a ſymptom; and the diſeaſe was placed under the genus Apoplexia,

(*a*) Ασφυξια. Deletis omnibus vitæ indiciis, accedente etiam ſuffocatione, mortis imaginem ita refert ut meritò dubitetur, vitamne, an mortem predicare fas ſit.——Inſt. Pathol. H. D. Gaubii.

Apoplexia, where it ſtill remains (*a*). If, however, we are to conſider the primary morbid affection of the body as the diſeaſe itſelf (*b*), and all the conſequent appearances only as ſymptoms; this diſeaſe is in the blood, and conſiſts in the preſence *of this black blood in the left ſide of the heart and arterial ſyſtem*; and the diminution of the action of the heart and arteries, and the blue colour of the face, &c. &c. are only ſymptoms: this diſeaſe, therefore, might with more propriety be named Melanæma (*c*), and claſſed with others which have ſome reſemblance to it.

As

(*a*) Synopſis Noſolog. Cullen. pag. 190.

(*b*) Status ille corporis humani viventis, quo fit, ut actiones homini propriæ non poſſint appoſitè ad leges ſanitatis exerceri, Morbus dicitur.

Inſt. Pathol. H. D. Gaubii.

(*c*) Ex μέλαν ἁιμα, ſanguis niger.

As there is no *Pyrexia* here, nor any *primary Neuroſis*, and as the alteration of colour in the ſkin is a conſtant ſymptom, would it not be more conſiſtent with the principles of noſological arrangement to place it in the claſs Cachexia, and order Impetigo? And ſince there is no genus for theſe diſeaſes, may we not propoſe one with with this name and definition?

MELANÆMA,

impedita ſanguinis venoſi in arterioſum converſio, cujus ſigna, Syncope, et livor cutis.

And this genus would afford an aſylum to ſeveral noſological wanderers that have not yet found a permanent reſting-place: for it is a natural conſequence of theſe experiments, that the diſeaſes which are brought on by hanging (*a*), by breathing fixed

(*a*) It is ſomewhat extraordinary that the greater part of practitioners ſtill ſuppoſe the death, which follows

fixed or phlogiſticated air, are all produced by this black blood going into the heart unchanged by reſpiration; and they ſhould be therefore placed in the ſame family (*a*): but, as name and arrangement are only of ſecondary importance, when the nature of a diſeaſe is aſcertained, it may perhaps be more

---

follows hanging, to be produced by compreſſion on the brain; notwithſtanding the number of facts in ſurgery which ſhow, that a preſſure on the brain, much greater than could be ſuppoſed to ariſe from any quantity of blood accumulated there by hanging, will not diminiſh the contractions of the heart immediately, nor often for ſeveral hours, and even days, afterward.

(*a*) Perhaps in this manner:

Melanæma à Submerſione,

——————— à Suſpenſione,

——————— ab Inſpiratione Aëris fixi,

——————— ab Inſpiratione Aëris phlogiſticati, &c.

more agreeable to general prejudice to retain the accuſtomed title Aſphyxia, and to arrange it as a ſymptomatic Syncope, with ſomething added to expreſs the primary affection: as

Aſphyxia à ſanguine venoſo in auriculam et ventriculum ſiniſtros tranſeunte.

Theſe, however, are only propoſals for the conſideration of Noſologiſts, which we willingly leave to their future determination.

SECTION

SECTION VI.

To determine the Condition of the Body in this Diſeaſe, and the Means of diſtinguiſhing it from Death itſelf.

OF animal bodies there are only two general conditions, Life and Death; and ſince by *death* we underſtand the privation of life, there can be no intermediate ſtate between them. Of the body in this diſeaſe, we can ſay with propriety only, that it is alive, or that it is dead. If it were really dead, it would neceſſarily follow, that the means, which are employed to recover it, in the different experiments of the Fourth Section, muſt be ſuppoſed to communicate life to dead matter, which is impoſſible: the

body is therefore alive, but with a degree of life leſs perfect than in the ordinary ſtate of health; and ſince a difference in degree does not occaſion an alteration in kind (*a*), the body muſt ſtill retain that principle which is the immediate cauſe of all the functions, that are performed in health (*b*); only it is not now excited to action; becauſe the external concomitant circumſtances, which operated upon it in health, are removed. Theſe external circumſtances are heat and reſpiration.

To

(*a*) Majus aut minus non variat ſpeciem.

(*b*) Hence it appears, that there is a ſtriking impropriety in the terms, which are commonly employed to expreſs the ſtate of the body in this diſeaſe, viz. "*ſuſpended life*," "*ſuſpended animation*," &c. and theſe terms ought to be laid aſide; becauſe they lead mankind to believe themſelves capable of *reanimating* or *reſuſcitating* a lifeleſs maſs, when they only cure a diſeaſe.

To aſcertain the ſeat of this principle, we inquire into the effects of the privation of heat and reſpiration on the living body.

It is generally known, that a ſmall diminution of the ordinary temperature of the body will not occaſion a ſuſpenſion of any of its functions: but it is alſo known, that a conſiderable diminution of the ordinary temperature of the body will occaſion a ſuſpenſion of the greater part of its functions (*a*). A certain degree of heat, therefore, in living bodies is indiſpenſably neceſſary to keep up the functions of health. But although the heat be indiſpenſably neceſſary, it is not in itſelf ſufficient to keep up theſe functions without reſpiration: for if heat be applied to the living body, when

(*a*) Flora Siberica, præfat. p. 72.

the different functions are ſuſpended, none of them will be recovered, until the reſpiration be eſtabliſhed; and the reſpiration is not always eſtabliſhed in this ſtate, in conſequence of the application of heat, but often requires artificial aſſiſtance (*a*). (See the Experiments with the amphibious animals in the Fourth Section.)

Since, then, the preſence of heat in the living body is not in itſelf ſufficient to keep up the different functions without reſpiration, the heat muſt not be regarded as the whole

---

(*a*) No one can deny that the reſpiration is ſometimes eſtabliſhed in this ſtate, in conſequence of the application of heat. Reaumur mentions a caſe of this diſeaſe, where a perſon was recovered, only by being expoſed to the rays of the ſun: and Nature ſeems to employ the ſame means to recover the hybernating animals from their torpor, a ſtate very ſimilar to this diſeaſe.

whole cauſe of the continuance of theſe functions, but rather as putting the body in a condition to produce them, when the effects of reſpiration are exerted upon it. And hence, when the natural temperature is conſiderably diminiſhed in this diſeaſe, the body is deprived of a condition indiſpenſably neceſſary to favour the operation of reſpiration in reſtoring the functions of health.

From the want of reſpiration the heart ceaſes to contract; becauſe the blood, which paſſes through the lungs, is an inſufficient ſtimulus to it; and the heart ceaſing to contract, all the other functions are ſuſpended. But if the temperature and reſpiration be reſtored to the body ſoon after the ceſſation of the heart, the natural contractions will be renewed, and all the other functions recovered. And ſince the con-

tractions are renewed by the application of the ordinary ſtimulus, the heart retains that principle (*a*), which is the immediate cauſe of its contractions, even after all the other functions are ſuſpended.

But if we attempt to reſtore the temperature and reſpiration to the body a conſiderable time after the ceſſation of the heart, its contractions will not be renewed, nor will any of the functions be recovered: and when the contractions are not renewed by the application of the ordinary ſtimulus, the heart has loſt that principle, which is the immediate cauſe of its contractions, and we have no means of reſtoring it.

From theſe facts it is evident, 1ſt, That the heart is the great ſeat of the principle of

(*a*) The principle of life.

of life in all the more perfect animals; 2dly, That the contraction (*a*) of the heart with the ordinary ſtimulus is the only mark of the preſence of this principle; and when the heart contracts under theſe circumſtances, the body is alive; but when it does not contract under theſe circumſtances, the body is dead: Life in the more perfect animals may therefore be defined, *The faculty of propelling the fluids through the circulating ſyſtem.*

And whenever the functions of an animal are ſuddenly ſuſpended, and the body puts on the appearance of death, it is always in our power to determine whether it be really dead, by reſtoring the temperature, and

(*a*) That action of the heart, by which it exerts the ordinary force to propel the blood along the circulating ſyſtem.

and by inflating the lungs with proper air. But, to render the deciſion complete, it will be neceſſary to regulate their application by a particular attention to the ſtate of the lungs, and to the immediate object of reſpiration. Theſe ſhall be conſidered in the next Section.

SECTION

SECTION VII.

To determine the beſt Means of curing the Diſeaſe.

THE means of curing this diſeaſe are ſo much anticipated in different parts of this Eſſay, that nothing remains to be added here, but a few obſervations on the manner of conducting the application of them.

To recover the ſuſpended functions, we muſt renew the contractions of the heart; (ſee Section the Fourth;) and this can be done by reſtoring to the body its heat and reſpiration: (ſee Section the Sixth.)

In every caſe therefore of this diſeaſe, the only object in the cure is to excite the contractions

contractions of the heart; and the only means neceſſary to be employed are the application of heat to the body, and air to the lungs: but as the operation of theſe powers will be more or leſs effectual, in proportion as they are regulated by a regard to the circumſtances of the body, it will be neceſſary to deliver ſome particular directions for the application of them.

When we attend a perſon in this diſeaſe, the firſt buſineſs is to examine the temperature of the body, and, if it be conſiderably below 98°, to order the application of heat: but, ſince the ſcale of heat is ſo very extenſive, it is neceſſary to determine the degrees of it beſt calculated to promote the recovery.

It is generally known from ſeveral familiar facts, that whilſt the circulation of the blood

blood continues, the temperature of the body may be raiſed many degrees above the natural ſtandard without deſtroying the principle of life: but it appears on the other hand, from the reſult of many attempts to recover the hybernating animals from their torpor, that when the circulation of the blood has ceaſed, and the temperature of the body is reduced near the freezing point, if heat be applied either very ſuddenly, or in a very high degree, the principle of life is ſoon deſtroyed; whereas, if it be applied gradually, and in a very low degree, to the ſame animals in the ſame circumſtances, the principle of life is often excited to action, and the functions are ſoon reſtored.

The effects of heat therefore are extremely different in different ſtates of health and diſeaſe; and the greateſt caution is required

required in deducing any inference from analogy to regulate the application of it as a remedy.

But ſince the condition of the body in this diſeaſe is nearly the ſame as in the ſtate of torpor, and ſince the progreſſion of the recovery is alſo the ſame; it can ſcarcely be unſafe to conclude, that heat will produce the ſame effects on the body in this diſeaſe, as in the torpid animals.

To favour the recovery then moſt effectually, the application of heat ſhould be conducted on the ſame plan, which Nature has pointed out for the torpid animals. It ſhould be applied very gradually and uniformly; and it may be raiſed to 98°, but not further than 100°.

When the body is warmed uniformly, and the heat of the interior parts about 98°,

we

we direct our attention to the ſtate of the thorax; and if the patient make no attempt to inſpire, we proceed to inflate the lungs with air.

When a perſon is in health, the object of reſpiration is to change the quality of the blood paſſing through the pulmonary veſſels, and to fit it to excite the contraction of the left ventricle of the heart: but in this diſeaſe the pulmonary veins, the ſinus venoſus, and auricle, contain a quantity of blood, which has paſſed through the lungs without undergoing this neceſſary change: the firſt object therefore in inflating the lungs is to change the quality of the blood in the trunks of the pulmonary veins, ſinus venoſus, and auricle, to fit it for exciting their contractions. This muſt be done by introducing the air ſo deep into the lungs, that it may exert a chymical action on the blood in theſe cavities.

For

For this purpoſe, a great quantity of air muſt be introduced at each inflation; for if only 12 cubic inches be injected at a time, this ſmall quantity will occupy the larger branches of the trachea, and conſequently only a ſmall number of the pulmonary veſſels will be expoſed to its action: but if a much greater quantity of air be forced in at each time, ſome of it will paſs into all the more remote cells; and when they are thus uniformly diſtended, the pulmonary veins, the ſinus venoſus, and left auricle, will be expoſed as much as poſſible to its action, and ſome of the altered blood may be forced into them from the ſmaller veſſels.

On this account we ſhould introduce upwards of 100 cubic inches of air into the lungs of an adult at each inflation (*a*), and

(*a*) This direction is further confirmed by the circumſtances of ſpontaneous recoveries from an ordinary Syncope: the firſt inſpiration is generally very full.

and it muſt be carefully drawn out again before more be introduced.

But one difficulty ſtill remains: there is ſometimes a quantity of water inſinuated into the ſmall branches of the trachea, and into the air-cells; (ſee the Second Section;) and if the lungs be inflated in this ſtate, the water will occupy thoſe places where the freſh air is principally required: and although the lungs be inflated with the utmoſt care and attention, it may be impoſſible, on this account, to apply the freſh air, ſufficiently near the ſinus venoſus and left auricle, to change the quality of the blood they contain (*a*): in all caſes, therefore, where the quantity of water is conſiderable,

(*a*) I think I have ſeen this opinion verified ſometimes in young animals, where the lungs contained a conſiderable quantity of froth after ſubmerſion:

ſiderable, we muſt remove ſome of it, before the air is introduced. Sometimes a ſmall portion of it will paſs out by its own gravity, when the head is reclined; and ſtill more may perhaps be taken away by an inſtrument ſo contrived, on the principles of the pump, as to exhauſt the lungs of a part of their contents.

For this purpoſe, I propoſe the inſtrument A B C D E. The braſs cylinder A B contains

---

if I inflated them fully in this ſtate, the colour of the blood in the ſinus venoſus and left auricle was not apparently changed, and the heart did not renew its contractions, although it ſtill retained the faculty of contraction. Some ſimilar caſes are mentioned, by the Dutch writers, in the human ſubject after ſubmerſion. The perſons inſpired ſeveral times of themſelves, but ſtill they did not recover; and this failure may perhaps be accounted for in the ſame manner.

D
d
b
A
a
B
E
C

contains 100 cubic inches of air, and communicates with the atmoſphere by the ſmall circular opening *a*. The piſton D E is of wood, and lined with a ſoft ſubſtance at the bottom E, ſo as to be air-tight. The two openings *d*, *b*, are to allow the air to eſcape, when the piſton is drawn higher than the circular opening *a*. The tube C is for the attachment of a ſmaller one, to be inſerted into the noſe, larynx, or trachea (*a*).

If the lungs are to be inflated, the extremity of the ſmall tube muſt be inſerted into one of the aërial paſſages, and the others

 properly

(*a*) I am favoured with this inſtrument by Dr. Nooth, a Gentleman diſtinguiſhed as much for liberality as genius, to whom the Arts are indebted for ſeveral valuable inventions, which are commonly attributed to others.

properly ſhut. The piſton being drawn up, and the orifice *a* cloſed with the finger, we preſs down the piſton, and force the contents of the cylinder into the lungs. A few ſeconds after, we draw up the piſton, and the air paſſes from the lungs into the cylinder again. Then we remove the finger from the orifice *a*, preſs down the piſton, and the greater part of this expired air eſcapes into the atmoſphere. After this, we draw up the piſton a ſecond time, while the orifice *a* continues open, and a volume of freſh air enters into the cylinder, which may be forced into the lungs in the ſame manner.

But where it is neceſſary to extract water from the lungs before the inflation, we begin the proceſs with the piſton down; and when the ſmall tube is inſerted, as before, we draw up the piſton, until the lower part

E is contiguous to the orifice *a*: the water will then riſe up from the lungs into the fauces, or cylinder. If the water riſe into the cylinder, it may be evacuated by detaching the tube C from its connexion with the ſmaller tube: and this may be repeated once or twice; but always with great caution, leſt the pulmonary veſſels be injured. Then we proceed to inflate the lungs in the manner juſt deſcribed (*a*).

If

(*a*) Other machines have been lately propoſed to inflate the lungs in this diſeaſe, and particularly one by Mr. Kite of Graveſend, and another by Mr. Hurlock of St. Paul's Church-yard; two ſurgeons of conſiderable eminence and reſpectability. I have not yet employed theſe machines on animals, but am informed, that they are extremely well calculated for the purpoſe. It appears, however, that they are encumbered with valves; and in the choice of an inſtrument for a buſineſs of this kind, which is ſometimes truſted to the awkward and ignorant

If the inflations be continued carefully and ſlowly for ſeveral minutes in this manner, the contractions of the heart will be gradually renewed, and the other functions will ſoon return, without any other inconvenience than a difficult and ſterterous reſpiration, which often continues a ſhort time afterward: this inconvenience ariſes from ſome water ſtill remaining in the lungs, which will be gradually evaporated by the expired air.

In ſituations where dephlogiſticated air can be procured to inflate the lungs, it ſhould

---

part of mankind, I ſhould be diſpoſed to prefer the moſt ſimple, where there are neither valves, nor ſtop-cocks, and where the quantity of air to be injected is clearly meaſured: but the value of theſe different inſtruments muſt be determined by future experience.

ſhould be always preferred to atmoſpheric air. I have employed it in ſeveral inſtances in the ſmaller animals, and the recovery was commonly more expeditious than where atmoſpheric air was uſed; but I have not yet been able to recover an animal with dephlogiſticated air, where good atmoſpheric air had been ineffectual.

Several other remedies have been recommended for this diſeaſe by different writers, and many of them are ſaid to have been employed with ſucceſs; but as the circumſtances of their application, and the progreſſive changes in the body, are not minutely detailed, nothing can yet be ſaid to be determined in favour of their particular efficacy. If indeed we were to judge of them from the hiſtory of their introduction, or from their ordinary operation on living bodies, little aſſiſtance would be expected from them.

Some of them were ſuggeſted from a falſe notion of the nature of the diſeaſe (*a*); others, from a miſtaken opinion of the principal ſeat of life (*b*); and ſome, from an ignorance of the moſt effectual means to ſolicit the principle of life into action (*c*): and none of

---

(*a*) Bleeding, friction, and ſuccuſſion. See Mémoires ſur les Noyés, &c. par Monſ. *Louis Nederlandiſche Jaarboeken*, April 1758. *Diſſertatio de Syncope, Auctore Hieron. Queye.*

(*b*) The application of different ſubſtances to the ſkin, the ſtomach, the inteſtines, the parts of generation, the noſe, the fauces, the extremities of the fingers, &c. *Diſſertatio de Cauſâ Mortis Submerſorum, Auct. Jacob Gummer.*

(*c*) The employment of electricity, alcohol, volatile alkali, tobacco, eſſential oils, and all the acrid and ſtimulating ſubſtances.

Tract. Iſnard. pag. 13. Obſ. 5.

Ranchinus in Tract. de Morb. ſubit. Cap. 12.

Ælius in Tetrab. Cap. 49.

Le Voyage d'Acadie, pag. 190.

of them appear fitted to excite the natural contractions of the heart by direct agency: but ſince they are now introduced into practice on the authority of ſeveral learned ſocieties, experiment alone ought to decide concerning their efficacy.

In the caſes recorded of their ſucceſsful application the bodies were warmed: now it has been ſhown in the Sixth Section, that the preſence of heat alone is often ſufficient to produce a recovery; and therefore, whilſt the remedies are applied under theſe circumſtances, the ſucceſs cannot with propriety be attributed to their operation: and if they be applied when the temperature of the body is ſo low, that warmth cannot be ſuppoſed to contribute to the recovery, it is known from experiment, that no ſenſible change will be produced: the concurrence of heat is therefore neceſſary to their ſucceſs.

Still,

Still, however, it may be ſuppoſed, that the concurrence of reſpiration is not neceſſary.

But this may be determined by applying theſe remedies in conjunction with heat, by attending to the progreſſive changes in the body during their ſucceſsful application, and by obſerving if the other functions return before the reſpiration be renewed.

I applied theſe remedies ſingly to ſeveral animals under theſe circumſtances, and attended carefully to the progreſſive changes in the body: ſome of them were recovered, and others were not; and in all the ſucceſsful caſes the progreſſion of the recovery was as follows. The organs of reſpiration began firſt to move, two or three inſpirations followed; the contractions of the heart were gradually renewed, and then the other functions followed.

In

In theſe caſes it appears, that theſe remedies were not often attended with ſucceſs; and even when they were ſo, the other functions did not return until reſpiration began: the concurrence of reſpiration is therefore neceſſary to their ſucceſs; and if it could be granted, that they entirely, or even in part, occaſioned the recovery in theſe caſes, it muſt evidently be by operating on the organs of reſpiration, by exciting them to action, by producing an inſpiration, and applying to the heart its natural ſtimulus; thus inducing it to contract, and to reſtore the ſuſpended functions.

Hence, if we allow to theſe remedies all the efficacy that partiality can claim, it can only be ſaid, that they ſometimes produce by indirect means, what may be always done directly by the method we have recommended: ſurely then we ought not to

heſitate

heſitate in preferring a remedy which can be applied directly, and which operates with certainty and expedition, to one that is ſlow, indirect, and uncertain.

In ſituations, indeed, where the means of artificial inflation cannot be immediately procured, theſe remedies may be employed for the moment; but every perſon ought to be appriſed of their inſufficiency, and of the neceſſity of employing artificial inflation, even after their application has failed.

Haller mentions a caſe, where the ordinary remedies had been employed an hour without any ſenſible effect, and yet by inflating the lungs the patient was quickly recovered (*a*); and I have often ſeen the ſmaller

(*a*) Diſputat. ad Morb. curand. et Hiſt. pertinent. tom. vi. pag. 318.

ſmaller animals recovered by inflation, after the other remedies had failed.

Notwithſtanding theſe facts and concluſions, ſome practitioners may be ſtill diſpoſed to think with the ancients. With ſuch, authority will be more powerful than argument; yet, ſince thoſe who will not be ſhaken by the labour of youth, may ſometimes yield to the judgement of age, we ſhall venture to addreſs them in the language of the candid Sydenham.

" Atque hoc mihi, ſuffragante experientiâ
" multiplici, compertiſſimum eſt: experi-
" entiâ, inquam, optimâ duce, et magiſtrâ,
" ad cujus leges et normam niſi exerceatur
" Medicina, eam prorſus exulare ſatius eſſet:
" luditur enim (quod aiunt), de corio hu-
" mano plus ſatis, cum hinc empirici, ne-
" que morborum hiſtoriam, nec methodum

" medendi

" medendi callentes, et receptis tantum
" freti; iſthinc Sciolorum vaniſſimi ſpem
" omnem in affectato artis ambitu, et ſpe-
" culationibus utrinque pari fere momento
" diſceptatis ponentes. Ea demum Praxis,
" eaque ſola ægris mortalibus opem feret,
" quæ indicationes curativas ex ipſis mor-
" borum phænominis elicit, dein firmat
" experientiâ, quibus gradibus magnus Hip-
" pocrates ad cœlum aſcendit."

FINIS.